Incorporating uncertainty and risk into forestry financial evaluations

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THE HOME-GROWN HOMES PROJECT

06 Economic aspects of woodland creation for timber production

Incorporating uncertainty and risk into forestry financial evaluations

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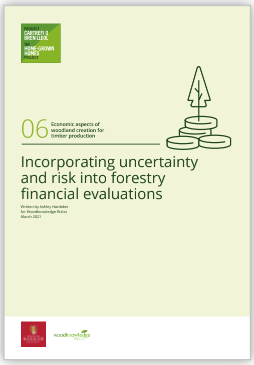
06
Incorporating uncertainty and risk into forestry financial evaluations

Guidance

This document is part of a series of *guidance notes* aiming to provide practical information for farmers and other landowners interested in investing in forestry. It is designed to help develop a first understanding of economic evaluation of afforestation projects. As such it introduces the basic steps involved in the assessment of such projects to allow some preliminary due diligence when considering an investment in forestry. This does not replace a full assessment and advice by a chartered forest manager.

There are six documents in this series

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Incorporating uncertainty and risk into forestry financial evaluations

Predicting future outcomes from an afforestation project with any certainty is problematic, not least because of the long timeframes involved. Like agricultural outputs, forestry crops are influenced by a number of uncontrollable factors (e.g., climate, markets or policy). However, while agricultural outputs work on an annual basis, in forestry the impact of a wide range of these factors needs to be accounted for over several decades. In this guidance note we introduce some simple techniques for incorporating the potential effects of uncontrollable and unpredictable factors into financial evaluation of forestry investments.

Uncertainty and risk

Uncertainty and risk refer to two positions on a spectrum of knowledge (Figure 1).

Ignorance	We know nothing
Uncertainty	We know what might happen and what the outcomes might be, but not the probablity of what might happen
Risk	We know what might happen but we ALSO know the probablity of what might happen and hence the outcome
Certainty	We know exactly what will happen and precisely what the outcome will be

Figure 1: Spectrum of knowledge (Price 1989)

Perfect certainty and complete ignorance are both rare in decision making. Most decisions are made under uncertainty and risk as is the case with forestry investment. While *uncertainty* refers to the relative lack of certainty, *risk* refers to the known probability of a certain event happening (e.g., that an extreme storm will blow down your woodland). The main sources of uncertainty and risk that an afforestation project might face are outlined in Table 1. For more information see *Elements of Cost-Benefit Analysis for Forestry Investments*.

Table 1: Sources of uncertainty and risk facing an afforestation project

Source	Description
Environmental	The primary hazards are extreme climatic events (leading to fires, droughts or trees being blown down by extreme winds) or attacks by pests (e.g. insects or browsing animals) and pathogens (fungal, bacterial or viral).
Technological	Technological advances during the forest rotation may alter the uses for certain forest products or means of managing a woodland or harvesting timber.
Human	Arson and accidental fires from human activity pose a threat to a commercial timber crop.
Economic	Timber is sold into markets that are subject to fluctuations and unexpected fluctuations of rise and fall driven by global trends over time.
Policy environment	During the length of a forest rotation, many governments will come and go. The policy environment within which the legislation and guidelines affecting how woodland should be managed will change over time.

Incorporating uncertainty into financial evaluations

Creating an overview of the relevant facts will help accounting for uncertainty in financial evaluation. Table 2 indicates how this can be done in a logical way:

1. Outline the *option* being evaluated (e.g., an upland or lowland conifer plantation). This is controlled by the decision maker.
2. Identify the *condition* relating to one of the sources of uncertainty (see Table 1) over which the decision maker has no control (e.g., market conditions change and timber prices fall).
3. Identify the *effect* the source of uncertainty will have on the *option* under the *condition* (e.g., revenues are reduced).

Once the facts are established the impact of the change in condition on the profitability of the option (e.g., an upland or lowland conifer plantation) can be calculated using a *sensitivity analysis.* Sensitivity analysis shows how outcomes vary with different conditions and effects. It constitutes the final step in a financial evaluation of a forestry investment (see *Financial Evaluation of Afforestation Projects - Basic Steps*). The example calculation demonstrates how this is applied.

Table 2: Two examples of environmental and economic uncertainty.

Source	Option	Condition	Effect
Environmental (extreme winds)	Establish a plantation woodland in the uplands/ lowlands	A major storm blows over or damages some of the timber crop before it is harvested	50% of the timber crop will be lost
Economic (market fluctuation)	Establish a plantation woodland in the uplands/ lowlands	Markets slump and the price of timber falls	Revenues from harvested timber will be 20% lower than forecast

Example Calculation: Sensitivity Analysis

Using the two examples of uncertainty from Table 2, their impact on the profitability of the upland and lowland conifer options previously introduced (see *Financial Evaluation of Afforestation Projects - Basic Steps*) is estimated by calculating the net present values (NPVs) in the discounted cash flow three times (see Table 3):

- 1x without any changes to market prices or timber losses (blue).
- 1x with timber prices reduced by 20% (orange).
- 1x with harvestable timber volumes reduced by 50% (green).

Table 3: Discounted cash flow including sensitivity analysis (£ per hectare). Present values (PV) are calculated using a discount rate of 3%.									
		Upland conifer option				**Lowland conifer option**			
Year	Description	PV costs[1]	PV grants[1]	Revenues	PV revenues[2]	PV costs[1]	PV grants[1]	Revenues	PV Revenues[2]
1-4	Fencing, ground prep, planting, weeding & beating up	8,675				8,675			
1-12	Fencing, planting, maintenance and premium payment		9,194				9,194		
40	Timber maincrop (lowland option)							8,670	2,658
50	Timber maincrop (upland option)			10,425	2,378				
40	Timber maincrop (lowland option)							4,335	1,329
50	Timber maincrop (upland option)			5,212	1,189				
40	Timber maincrop (lowland option)							6,936	2,126
50	Timber maincrop (upland option)			8,340	1,902				
Net present value (no loss of timber crop or fall in timber prices)		(9,194 + 2,378) – 8,675 = 2,897				(9,194 + 2,658) – 8,675 = 3,177			
Net present value (50% loss of timber crop)		(9,194 + 1,189) – 8,675 = 1,710				(9,194 + 1,329) – 8,675 = 1,850			
Net present value (20% fall in timber prices)		(9,194 + 1,902) – 8,675 = 2,423				(9,194 + 2,126) – 8,675 = 2,647			

An investment is acceptable if NPV > 0 even when accounting for the uncertainty of crop losses and market fluctuation. Under this condition, investing in both the upland and lowland conifer options are acceptable decisions for an upland and lowland farmer respectively. The worst circumstance for the two options is a 50% loss of timber crop. The lowland option has the *highest net present value*. Using *Wald's maximin criterion* (see Box 1), the rational decision under uncertainty would be to choose the lowland option.

Box 1: Wald's Maximin Model

Faced with a choice between alternative options, decision makers should adopt the option that gives the best outcome in the worst circumstance. Wald's maximin criterion is a pessimistic criterion which expects the worse of two outcomes. It is applicable to investors choosing between a number of sites for afforestation, or to farmers and other landowners choosing between two afforestation options for a single site. For other decision making criteria see *The Theory and Application of Forest Economics* or *Forestry Economics*.

Incorporating risk into financial evaluations

The primary difference between uncertainty and risk is that the latter involves knowing the probability that something will happen. Sensitivity analysis is used to determine the effect of uncertainty surrounding a particular condition on the profitability of an afforestation option.

In reality, a major storm might cause significant damage to a timber crop, but the probability of this happening could be relatively low. The results in Table 3, shows the very worst outcomes that might occur: a major storm and market fluctuation significantly reducing the profitability of investing in a forestry enterprise. However, this overlooks the fact that the worst may not happen.

If the risk is known, calculating the *mean expected value* is a way to account for the effects of something being risky in financial evaluations, rather than just being uncertain. This provides a realistic view of how certain factors outside the decision maker's control affect the profitability of an investment.

The *mean expected value* is the sum of the outcomes for a given option under the whole range of conditions (relating to a source of risk), with each outcome weighted by its probability. The mean expected value accounts for what might happen, what effect this might have and the probability of this happening.

Calculating the mean expected value involves the following five steps:

1. Classify the conditions relating to the risk.

2. Determine the outcome (e.g., NPV) of each option under each condition and enter it into an outcome matrix.

3. Determine the probability of each condition. In many situations, the probability of something happening can be estimated from historical records, use of model-based decision support tools (e.g. ForestGALES for wind damage) or consultation with experts. Where the probability of something happening cannot be estimated using any of the above, *Laplace's equal probability rule* can be used. This rule states that if nothing is known about the probability of a condition, each condition should be assumed to be equally likely.

4. Weight each outcome under each condition by the probability of it occurring (the *weighted outcome* = [probability of condition] × [outcome under condition])

5. Add up the weighted outcomes for all conditions for each option.

This summed figure is the mean expected value of the option.

Mean Expected Value

For the financial evaluation of the upland and lowland conifer options (see previous example) the effects of two types of risk - environmental (extreme winds) and economic (market fluctuation) - need to be considered.

Step 1 Classify conditions
For the environmental risk relating to extreme winds, one condition describes the occurrence of a storm while a second describes the non-occurrence of a storm. For the economic risk relating to market fluctuation, one condition describes a fall in markets and a second describes no fall in markets. See table 4 for both.

Step 2 Determine the outcome
The outcome (e.g., *net present value*) of each option under each condition is taken from the *sensitivity analysis* (Table 3) and entered in the outcome matrix shown in Table 4.

Step 3 Determine the probability
The probability of a major storm blowing over or damaging some of the timber crop is estimated to be 0.05 (i.e., there is a 1 in 20 chance of the timber crop blowing over in any given year), the probability of the crop not blowing over is then 0.95 (Table 4).

For the purpose of this example, Laplace's equal probability rule is applied to the risk of market fluctuation, assuming that the probability of markets falling and markets not falling is 0.5 (Table 4). In reality, the probability of both an upland and lowland crop blowing over will be different. Site specific estimates can be derived from the Forest Research Forest Gales decision-support tool.

Step 4 Weight each outcome
The weighted outcomes under each condition are shown in Table 4.

Step 5 Add up weighted outcomes
The mean expected value of the upland and lowland options under both environmental and economic risk is shown in Table 5. Given that an investment is acceptable if NPV > 0, even when accounting for the environmental and economic risks, investing in both the upland and lowland conifer options remain acceptable isolated decisions for an upland and lowland farmer respectively. Incorporating risk into the calculation, rather than just uncertainty, indicates that a forestry investment might still be highly profitable even in the face of risks from major storms or market fluctuations.

Note: Colours link back to the sensitivity analysis in Table 3

Table 4: Outcome matrix

			Outcome (NPV £ per hectare)		Weighted Outcome (NPV £ per hectare)	
Source of risk	**Condition**	**Probability**	**Upland option**	**Lowland option**	**Upland option**	**Lowland option**
Environmental (extreme winds)	A major storm blows over or damages some of the timber crop before it is harvested.	0.05	1,710	1,850	1,710 × 0.05 = 86	1,850 × 0.05 = 93
	There is no storm and all timber is harvested.	0.95	2,897	3,177	2,897 × 0.95 = 2,752	3,177 × 0.95 = 3,018
Economic (market fluctuation)	Markets slump and the price of timber falls.	0.50	2,423	2,647	2,423 × 0.5 = 1212	2,647 × 0.5 = 1,324
	Markets do not slump and timber prices are unaffected.	0.50	2,897	3,177	2,897 × 0.5 = 1,449	3,177 × 0.5 = 1,589

Table 5: Mean expected values

Source of risk	Mean expected value (£ per hectare)	
	Upland option	Lowland option
Environmental (extreme winds)	86 + 2,752 = 2,838	93 + 3,018 = 3,111
Economic (market fluctuation)	1,212 + 1,449 = 2,661	1,324 + 1,589 = 2,913

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Practical Guidance & Advice

In this guidance note we have introduced some methods to incorporate uncertainty and risk into financial evaluation of afforestation projects. These tools allow decisions to be informed by evaluation of how uncontrollable factors might affect the profitability of an investment.

We hope that this will help you undertake some preliminary due diligence when considering whether to adopt a forestry enterprise or invest in an afforestation project. Before making the final decision we recommend seeking further advice and guidance from a *forest manager or agent*.

You can find more detailed information on financial evaluations of forestry investments *here*:

01 Financial Evaluation of Afforestation Projects - Basic Steps
02 Evaluating the Financial Costs of Forestry
03 Revenue from Forestry Enterprises
04 Accounting for Time
05 Alternative Tools for Financial Evaluation of Forestry
06 Incorporating Uncertainty and Risk

Technical Information

The Theory and Application of Forest Economics. Price, C. Blackwell 1989

Elements of Cost-Benefit Analysis for Forestry Investments. Cambell, H.F. European Forest Institute 2014

Forestry Economics. Wagner, J.E. Abingdon: Routledge 2012

Forest Gales (Forest Research) online tool is available at *www.forestdss.org.uk/geoforestdss*

About the author
Ashley Hardaker is an interdisciplinary researcher at Bangor University interested in decision analysis in relation to land use, forestry, agroforestry and agricultural systems. He is particularly interested in research to inform decision making surrounding woodland creation in agricultural systems and how they can be designed to deliver public and private economic benefits. He engages with a range of research disciplines including ecosystem services, GIS, economics and operations research. The author is grateful for contributions to these briefing notes from Prof. John Healey of Bangor University

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